Technical Advisory for Flammable Hazardous Substances
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1. Introduction

Fire or explosion at work is a hazard that can cause serious injuries, deaths and damage to property. Highly flammable substances like gasoline and solvents are the most obvious sources but less apparent substances such as food, wood and metal dusts have also been known to explode and cause major fires.

This Technical Advisory (TA) aims to provide practical guidance on measures that can be taken to ensure the safety and health of workers who may be exposed to flammable hazardous substances at work. In this TA, “Flammable Hazardous Substances” refer to substances with inherent fire hazards.

2. Basic Concepts of Fire and Explosions

**Fire** is the process of a fuel (such as solvents or gasoline) combining with oxygen to produce heat.

**Explosions** are due to the violent expansion of gases, releasing large amounts of energy rapidly. The effects of explosions are fast-moving pressure waves and shock waves, which can damage equipment, destroy buildings and shatter windows.

**How do fire occur?**

Three elements – Fuel, oxygen and an ignition source such as heat, are all needed to be present in the correct concentration for a fire to start or an explosion occur:

- **Oxygen** is present naturally in the air around us.
- **Fuel** keeps a fire burning.
- **Ignition source** provides energy to initiate a fire.
There is no fire when any one of the three elements is eliminated or removed.

- Remove air to smother fire. Fire cannot burn without oxygen.
- Remove fuel sources. E.g. prevent build-up of combustible or flammable debris will decrease the likelihood of a fire.
- Keep sparks or other ignition sources away from fuel sources.

### Examples of Fuel

<table>
<thead>
<tr>
<th>Liquids</th>
<th>Gasoline, acetone, pentane, ammonia, ethylene oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gases</td>
<td>Acetylene, propane, carbon monoxide</td>
</tr>
<tr>
<td>Solids</td>
<td>Rubber, plastics, wood, plastic foams, packaging, textiles, sugar dust, wood dust, flour dust</td>
</tr>
</tbody>
</table>

### Examples of Ignition Sources

Sparks, open flames, welding arc, static electricity, heat, friction, motor starter, cigarette ember, pilot light
Case Study 1
Explosion of an oil drum when cut with a gas torch

The Incident
A drum, which was previously used for containing waste oil, exploded when a worker was cutting it with an oxy-acetylene gas torch. The worker suffered serious head injuries from the explosion and died two days after the accident.

Findings
• The explosion was due to the ignition of the remnant waste oil in the drum by the oxy-acetylene cutting operation.
• No risk assessments were conducted for hot work.

Lessons Learnt
Before carrying out any hot work, a careful assessment of the associated risks involved should be made. In the assessment, other alternative or safer methods of work such as cold cutting technique should be considered instead of hot work.

Upon ascertaining that hot work is necessary, the oil drum should first be rendered gas-free by cleaning, purging or steaming, or inerted before hot work commences. Additionally, safe work procedures must be established and implemented to ensure that hot work can be carried out safely without endangering the safety of workers and other workers in the vicinity of the hot work.
3. Combustible Dust

Materials such as wood, food, metal dusts can cause explosions due to the dispersion of fine combustible particles, when in sufficient quantities and concentration and under favourable conditions, such as air, heat, fuel, dispersion and confined environment.

How do dust explosions occur?
A dust explosion can occur when the following conditions exist at the same time:
1. Fuel, i.e. combustible dust of sufficiently small particle size;
2. Air;
3. Dispersion of the dust into the air;
4. A confined environment (e.g. a silo); and
5. An ignition source (e.g. heat).

Examples of combustible dusts are:
- Wood dust.
- Rubber dust.
- Plastic dust and additives (e.g. polyethylene, resin dust).
- Metal dust (e.g. aluminium, chromium, iron, magnesium, zinc).
- Food and grain dust (e.g. sugar, spice, starch, flour, animal feedstock).

Implement dust control measures:
- Establish effective dust control measures to prevent and reduce the escape of dust from processing equipment to the environment, e.g. dust collecting system.
- Replace combustible dust with safer alternatives e.g. ready-to-use materials.
- Establish and implement good housekeeping practices to keep work places clean and safe, such as cleaning at regular intervals to prevent the accumulation of dust.
- Design building elements and arrange equipment to reduce dust accumulation. Use features such as smooth, easy-to-clean walls and sloped surfaces.
Case Study 2
Combustible dust explosion in a food manufacturing company

The Incident
A worker was cutting the support of an old conveyor pipe system with a cutting torch when flour from the silo fell out from the bottom opening of the silo. Mixed with the surrounding air, a flash fire was triggered and a small explosion followed thereafter. The worker immediately turned off the cutting torch.

The injured worker suffered burns on his arms, face and parts of the body, while a co-worker who came to his rescue suffered minor burns. The platform of the silo and electrical wiring were also damaged.

Lessons Learnt
• Tapioca flour is a combustible material. A flash fire can be triggered in the presence of an ignition source, for example, the flame of the cutting torch.
• A safe work procedure was not implemented for the process

Materials such as wood, food, metal dust can cause explosions when dispersed in air, in sufficient quantities and concentration and under favourable conditions, such as air, heat, fuel, dispersion and confined environment.
4. Risk Assessment

Before starting work, a risk assessment should be carried out to identify hazards associated with it.

1. Assess risks based on:
   - the likelihood of accidents occurring as a result of hazards and
   - the severity of the consequences, should the accident occur.

2. Take appropriate measures to eliminate the hazards or to reduce the risk, and implement safe work procedures.

3. Adopt appropriate risk control measures by following the hierarchy of control.

4. Review risk assessments periodically.

5. Communicate these risks to all persons involved.

See Pg 17 for Example on Risk Assessment. For more information on Risk Assessment, please refer to the Guidelines on Risk Assessment available on MOM’s website.
## Risk Assessment (RA)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>• Form RA Team</td>
<td>• Identify hazards</td>
<td>• Estimate risk levels based on identified hazards</td>
<td>• Formulate control measures according to the Hierarchy of Controls: - Elimination - Substitution - Engineering controls - Administrative controls - PPE</td>
<td>• Keep risk assessment reports for at least 3 years.</td>
<td>Review risk assessments: - Once every 3 years; - Whenever new information on OSH risks surfaces; - When there are changes to work processes and / or; - After any accident / incident.</td>
</tr>
<tr>
<td>• Gather relevant information</td>
<td>• Identify potential accident / incidents</td>
<td>• Prioritise the hazards to be controlled</td>
<td>• Analyse and evaluate residual risk</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Communication**

- **Preparation**
  - Form RA Team
  - Gather relevant information

- **Hazard Identification**
  - Identify hazards
  - Identify potential accident / incidents

- **Risk Evaluation**
  - Estimate risk levels based on identified hazards
  - Prioritise the hazards to be controlled

- **Risk Control**
  - Formulate control measures according to the Hierarchy of Controls:
    - Elimination
    - Substitution
    - Engineering controls
    - Administrative controls
    - PPE
  - Analyse and evaluate residual risk

- **Record Keeping**
  - Keep risk assessment reports for at least 3 years.

- **Implementation & Review**
  - Review risk assessments:
    - Once every 3 years;
    - Whenever new information on OSH risks surfaces;
    - When there are changes to work processes and / or;
    - After any accident / incident.
5. Prevent Fire/Explosions Through The Hierarchy of Control

The following are examples of control measures associated with the handling of flammable and combustible substances.

Care must be exercised when selecting the measures to ensure that they are appropriate for the setup of your facilities.
Elimination
The first priority of control is to eliminate the risk at source. If the work or the process can be carried out without the need for the use of flammable or combustible substances, the risk of fire or explosion arising from the ignition of such substances will be eliminated.

Eliminate oxygen:
• Pipelines intended for carrying flammable substances should be purged to eliminate the presence of oxygen before use.

Eliminate fuel:
• Do not use oil or grease for lubricating valves, gauge connection or other parts of an oxygen system.

Substitution
Substitute flammable and combustible substances with safer alternatives:
• Use water-based substances or any non-flammable process instead of solvent-based substances.
• Use high flash point* substances instead of low flash point substances.
• Replace powders with materials in paste or pellet form.
• Use safer technologies or methods of work such as brush or roller application instead of spraying.

* Flash points of substances can be found from this TA’s Glossary or from Safety Data Sheets (SDSs).

Engineering Controls
Design safety into the process:
• Use spark-proof/explosion-proof, intrinsically safe or double insulated equipment.
• Use electrical devices that are enclosed in explosion-proof housings, which are designed to withstand an internal explosion and prevent the combustion from spreading beyond the enclosure.
• Bond and ground to minimise static electricity build-up when:
  - Carrying nonconductive liquids through metallic pipes, vessels, containers.
  - Pneumatically-carried solids.
  - Mixing immiscible liquids.
• Fireproof vessels, pipes, structures with insulation to minimise damage due to fires.
• Segregate flammable storage from the process areas. Dike vessels to contain and carry away spills.
• Design controls to fail safe. Add safeguards for safe shutdown during emergencies.
• Install ventilation and extraction systems to dilute flammable vapours with air to prevent fire/explosions.
• Apply local and/or dilution ventilation for works that cannot be carried out in the open, such as using a blower to supply fresh air to dilute the concentration of flammable substances.
• Install and maintain explosion vents of tanks or compartments, where appropriate.
• Install and maintain pressure relief vents for pressurised equipment.
• Ensure that construction material for tanks, piping, containers and vessels are suitable for flammable substances.
Administrative Controls

- Establish safe work procedures for work involving the storage, use, handling and disposal of flammable substances.
- Instil good housekeeping practices such as regular cleaning of any contamination or spills.
- Implement a safe storage and proper disposal system and store flammable substances away from heat or ignition sources.
- Keep lids on containers of flammable substances when not in use.
- Prohibit or control smoking.
- Do not allow naked flames in areas where flammable vapour is likely to be present.
- Implement a permit-to-work (PTW) system for hot work, or work involving flammable substances, such as spray painting in confined space.
- Institute an effective preventive maintenance programme for process equipment and protective equipment such as safety valves and alarms.
- Manage changes in processes, technologies and equipment to ensure operation integrity and safety.
- Use suitable electrical installations and equipment.
- Do not overload electric circuits and promptly report signs of electrical malfunction.
• Maintain and monitor equipment to prevent any possible defects that can lead to fire or explosions.
• Identify clearly the contents of containers, packaging, intermediate bulk containers (IBCs), portable tanks, multiple-element gas containers (MEGCs) and bulk containers containing flammable substances with the United Nations Recommendations on the Transport of Dangerous Goods (UNRTDG) flammable symbols.
• Obtain, use and disseminate information found in SDSs for flammable substances.
• Provide training on:
  - How to recognise the Globally Harmonised System of Classification and Labeling of Chemicals (GHS) pictogram for flammable substances.
  - Implementing the health and safety measures required for flammable substances, including storage, safe use and emergency procedures.
  - The appropriate use and maintenance of PPE.

**Personal Protective Equipment (PPE)**
Suitable PPE can be used to protect persons against fires and explosions. However, PPE should not be used as the only means of protection; it should be used in conjunction with the other risk control measures mentioned earlier.

• Selection of PPE:
  The selection of PPE should be suitable and compatible to the work, substances used and the work environment.
• Use of PPE:
  Workers should be familiar with the correct way of wearing and removing PPE.
• Maintenance of PPE:
  PPE should be properly maintained and stored to retain its protection efficacy.
6. Mitigate Consequences of Fire or Explosion with An Emergency Response Plan

**Emergency response planning**
A written emergency response plan should be established. Emergency response equipment should be kept on site, made readily available and accessible.

**Keep updated information on flammable substances and processes including:**
- Location, types and quantities of flammable and combustible substances.
- Possible accidents and emergency scenarios, with considerations to neighbouring buildings and installations.
- Protocols on activation of key personnel to oversee and direct the management of accidents, inclusive of chain of command and communication protocols.
- Suitable media for fire fighting, commensurate with the types of flammable substances involved and operational resources.
- Recovery procedures inclusive of clean-up and decontamination operations.

**Fire protection and fire fighting systems:**
- Maintain fire protection and fire fighting systems (e.g. PPE, fire extinguishers).
- Institute an inspection programme for emergency equipment and systems.
- Install, use and maintain fixed and mobile fire fighting equipment (e.g. hydrants, fire monitors, deluge systems, sprinkler systems, water curtains etc).
- Ensure good supply and drainage of fire-fighting water.
- Ensure access to extinguishers, hoses, alarms, fire exits and other emergency equipment and sprinkler heads are free from obstruction.
**Training:**
• Train and educate employees on fire fighting, safety-related operations and procedures (e.g. evacuation, location and use of emergency equipment, activation of alarms and communicator system).

**Drills:**
• Regularly review emergency action plans to ensure its continual relevance and currency.
• Conduct emergency drills at regular intervals, involving all persons at site to thoroughly validate and test the effectiveness and robustness of the plans.
### RISK ASSESSMENT FORM

**Company:** ABC Chemical Company  
**Process / Location:** Chemical mixing / Mixing Dept  
**Approved by:** Sim Bee Heong, Manager  
**Conducted by:**  
- Teo Ai Ling, Operator  
- Mohd Samat, Operator  
**Conducted on:** 1 Jul 2008  
**Last Review Date:** 3 Jul 2008  
**Approved on:** 3 Jul 2008  
**Next Review Date:** 3 Jul 2011

<table>
<thead>
<tr>
<th>No</th>
<th>Work Activity</th>
<th>Hazard</th>
<th>Possible Accidents / Ill Health &amp; Persons-at-Risk</th>
<th>Existing Risk Control (if any)</th>
<th>Likelihood</th>
<th>Severity</th>
<th>Risk Level</th>
<th>Additional Risk Controls</th>
<th>Action Officer, Designation (Date)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 2  | Mix chemicals D and E | Flammable vapour-air mixture in the flammable range with presence of ignition source | Fire and/or explosion leading to deaths, severe injuries, burns (Workers, visitors, sub-contractors, members of public) | • Fugitive flammable vapours from processes and ventilation are controlled by using enclosures, collection systems and equipment design.  
• Explosion venting is constructed within work area.  
• Smoking, open flames, sparks, heating are prohibited in process area.  
• Stationary metallic pipes, parts and equipment are bonded and grounded.  
• Maintenance programme implemented.  
• Management of change programme implemented.  
• Training provided for handling, use, storage, disposal of flammables substances.  
• Training provided on the use and maintenance of safety control measures  
• Emergency planning includes fire and explosion hazards | Occasional | Major | High | To separate mixing operations from other work areas by explosion-resistant barriers. | Sim Bee Heong, Manager (Jan 2009) |

Hazards and control measures listed are not exhaustive.
# 8. Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto-ignition Temperature (AIT)</td>
<td>The lowest temperature at which a flammable gas- or vapour-air mixture is capable of extracting enough energy from the environment to self-ignite.</td>
</tr>
<tr>
<td>Flammability Limits</td>
<td>The range of flammable vapour or gas-air mixture between the upper and lower flammable limits. The limits indicate the minimum and maximum concentrations in air of a flammable gas or vapour at which ignition can occur. Concentrations below the lower flammable limit (LFL) are too lean to burn; concentrations above the upper flammable limit (UFL) are too rich to burn.</td>
</tr>
<tr>
<td>Flash Point (FP)</td>
<td>Minimum temperature at which a liquid gives off enough vapour to form an ignitable mixture with air.</td>
</tr>
</tbody>
</table>
## 9. Flammability Characteristics of Liquids and Gases

<table>
<thead>
<tr>
<th>Compound</th>
<th>FP (°C)</th>
<th>LFL (vol% in air)</th>
<th>UFL (vol% in air)</th>
<th>AIT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>-17.8</td>
<td>2.5%</td>
<td>12.8%</td>
<td>465</td>
</tr>
<tr>
<td>Acetylene</td>
<td>NA (Gas)</td>
<td>2.5%</td>
<td>100%</td>
<td>305</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NA (Gas)</td>
<td>15%</td>
<td>28%</td>
<td>651</td>
</tr>
<tr>
<td>Benzene</td>
<td>-11.1</td>
<td>1.2%</td>
<td>7.8%</td>
<td>498</td>
</tr>
<tr>
<td>Butane</td>
<td>NA (Gas)</td>
<td>1.6%</td>
<td>8.4%</td>
<td>365</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>NA (Gas)</td>
<td>12.5%</td>
<td>74%</td>
<td>605</td>
</tr>
<tr>
<td>Diesel</td>
<td>52</td>
<td>0.6%</td>
<td>6.5%</td>
<td>254 to 285</td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>-28.9</td>
<td>3%</td>
<td>100%</td>
<td>429</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>NA (Gas)</td>
<td>4%</td>
<td>76%</td>
<td>500 to 571</td>
</tr>
<tr>
<td>LPG</td>
<td>NA (Gas)</td>
<td>1.6% (Butane)</td>
<td>8.4% (Butane)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.1% (Propane)</td>
<td>9.5% (Propane)</td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>NA (Gas)</td>
<td>5%</td>
<td>15%</td>
<td>537</td>
</tr>
<tr>
<td>Methanol</td>
<td>12</td>
<td>5.5%</td>
<td>44%</td>
<td>464</td>
</tr>
<tr>
<td>Pentane</td>
<td>-49</td>
<td>1.5%</td>
<td>7.8%</td>
<td>309</td>
</tr>
<tr>
<td>Petrol</td>
<td>&lt; -21</td>
<td>1.3%</td>
<td>7.1%</td>
<td>250</td>
</tr>
<tr>
<td>Propane</td>
<td>-104</td>
<td>2.1%</td>
<td>9.5%</td>
<td>450</td>
</tr>
<tr>
<td>Toluene</td>
<td>4</td>
<td>1.1%</td>
<td>7.1%</td>
<td>480</td>
</tr>
<tr>
<td>Turpentine</td>
<td>30 to 46</td>
<td>0.8%</td>
<td>6%</td>
<td>220 to 255</td>
</tr>
</tbody>
</table>

This table is extracted from
- NIOSH Pocket Guide to Chemical Hazards
- ILO International Chemical Safety Cards
10. Useful References

- Safe Working with Flammable Substances, HSE
  www.hse.gov.uk/pubns/indg227.pdf
- NIOSH Pocket Guide to Chemical Hazards
  www.cdc.gov/niosh/npg
- ILO International Chemical Safety Cards
- FM Global Property Loss Prevention Data Sheets 7-0, Causes and Effects of Fires and Explosions
- FM Global Property Loss Prevention Data Sheets 7-76, Prevention and Mitigation of Combustible Dust Explosions and Fire
- Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions, OSHA
  www.osha.gov/dts/shib/shib073105.html
- Emergency Response Program, EPA
  www.epa.gov/OEM/docs/chem/W-Chap-08.pdf
- Fact Sheet on Personal Protective Equipment, OSHA
- Globally Harmonised System of Classification and Labelling of Chemicals (GHS)
  www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html
- The following legislations:
  - Workplace Safety and Health Act
  - Workplace Safety and Health (General Provisions) Regulations
  - Workplace Safety and Health (Risk Management) Regulations
  - Workplace Safety and Health (Shipbuilding and Ship-repairing) Regulations 2008
    at www.mom.gov.sg/legislation/wsh.html
- More information and guidelines on Risk Assessment:
  www.mom.gov.sg/wsh/risk_management
- The Fire Safety Act and Fire Code:
  www.scdf.gov.sg/Building_Professionals/Publications/index.html
• Information on Fire Safety Licensing and Enforcement:  
  www.scdf.gov.sg/Building_Professionals/Fire_Safety_Licensing_and_Enforcement/index.html

• Guidelines on Emergency Response Planning:  

**Singapore Standards**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
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<tbody>
<tr>
<td>SS 510:2005</td>
<td>Code of practice on safety in welding and cutting (and other operations involving the use of heat)</td>
</tr>
<tr>
<td>SS 532:2007</td>
<td>Code of practice for the storage of flammable liquids</td>
</tr>
<tr>
<td>CP 55:1991</td>
<td>Code of practice for use and maintenance of portable fire extinguishers</td>
</tr>
</tbody>
</table>

**Singapore Standards can be obtained from:**  
SNP Corporation (Legal) Ltd  
Legal Publication Retail Outlet  
1 Kim Seng Promenade #18-01/06  
Great World City East Tower S(237994)  
Tel: (65) 6826 9691  
http://www.snpcorp.com/webshop

## 11. Acknowledgements

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